STATISTICS AND CLIMATE CHANGE

Professor Mark Berliner, Department of Statistics, Ohio State University
Co-Chair, ASA Climate Change Policy Advisory Committee (CCPAC)

Humans have been modifying the environment though processes associated with industrialization, population growth, and urbanization. One of the most important outcomes of these activities has been increased emissions of carbon dioxide (CO_2) resulting from fossil fuel burning as well as deforestation.

Anthropogenic emissions of CO_2 and other gases such as methane are important due to the greenhouse effect. The Earth absorbs energy from the sun. Through complicated processes, some energy reaching us from the Sun is trapped by constituents of the atmosphere, chiefly water vapor, but also CO_2 and others, leading to a warming of the surface and lower atmosphere. This *greenhouse effect* is a good thing, at least for us. Without it, the environment would be far colder. However, the extra emissions we are putting into the atmosphere create an enhanced greenhouse effect, leading to unnatural global warming. Global warming in combination with other anthropogenic effects may lead to very complex changes to our climate.

In 1988, the World Meteorological Organization and the United Nations Environment Program organized an international panel of scientists to consider climate change. This led to the establishment of the Intergovernmental Panel on Climate Change (IPCC). This large and influential organization recently shared the Nobel Peace Prize with Al Gore.

The latest IPCC report states: "Warming of the climate system is unequivocal" and that it is "very likely" caused by human activities (IPCC's use of the phrase "very likely" corresponds to a probability of at least 0.90). Beyond IPCC, there is a consensus among many scientists and politicians, as evidenced by both candidates in the most recent U.S. Presidential race, and the public that our climate is changing as a result of human activities.

The case for anthropogenic climate change involves three points: (1) climate is changing; (2) human activities have led to increases in CO_2 and other greenhouse gases, other pollutants, and created a variety of other changes such as in land-use, agricultural practice, deforestation, etc.; and (3) there are scientific arguments and large-scale computer models suggesting climate change due to anthropogenic inputs. No one of these points stands alone as a compelling argument. Scientific analyses of climate change require a quantitative integration of observations and modeling, and assessments of uncertainty.

Figure 1 offers a summary of the arguments offered by IPCC. This one result is not the basis for the sweeping claims made by IPCC; it is merely emblematic of the weight of evidence so many of us find compelling.

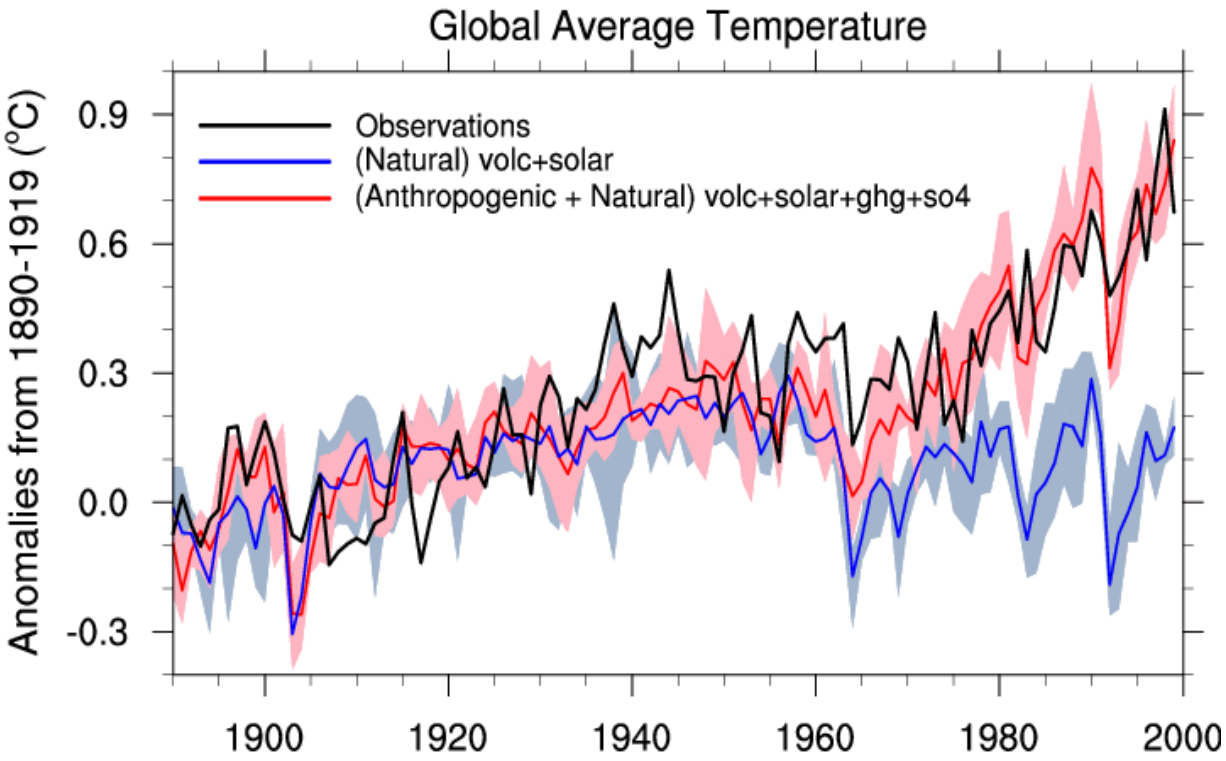

Figure 1. (Credit: IPCC web-site: *www.ipcc.ch*)

The figure plots time series corresponding to global averaged surface temperatures. Three primary series are plotted: (i) observed temperatures and temperatures summarizing the results of various climate system models computed using (ii) variations in natural forcings on the climate (e.g., solar energy) and (iii) those natural forcings in combination with anthropogenic inputs such as greenhouse gases and aerosols (particulate matter). Note that plots of the latter two series also include some indications of spread or uncertainty. Uncertainties are also present in the observations, though they are judged to be much smaller than those depicted for the model output. The key point is that though the models reasonably represent the observations in the early portion of the time period, model results using natural forcings fail to predict rising temperatures indicated by the latter portion of the observations. By also including anthropogenic as well as natural forcings, the models suggest warming patterns that match the observations.

The story is far from complete. Today, scientists, policy makers in both the public and private sectors, and the public are concerned about the impacts of climate change and their remediation. The role for statisticians in these efforts is crucial. Efficient decisions and policies require more than statements that climate change is real. They require quantitative predictions of impacts and measures of associated uncertainties.